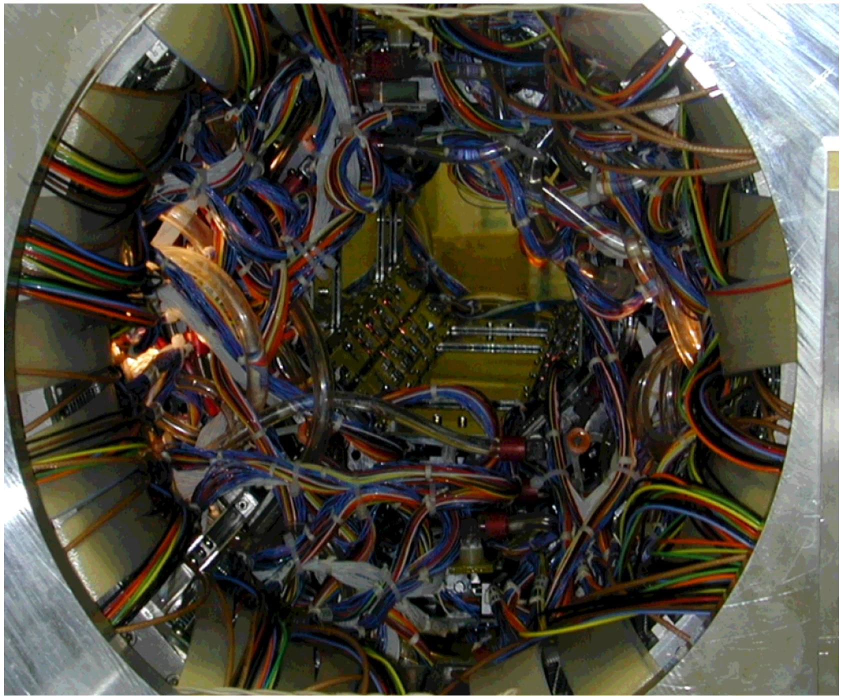
The SVT experience and possible Si-upgrades for STAR

- The SVT during year-2 running
- A large Silicon tracker for STAR
- A forward Silicon tracker for STAR

R. Bellwied, RHIC Workshop

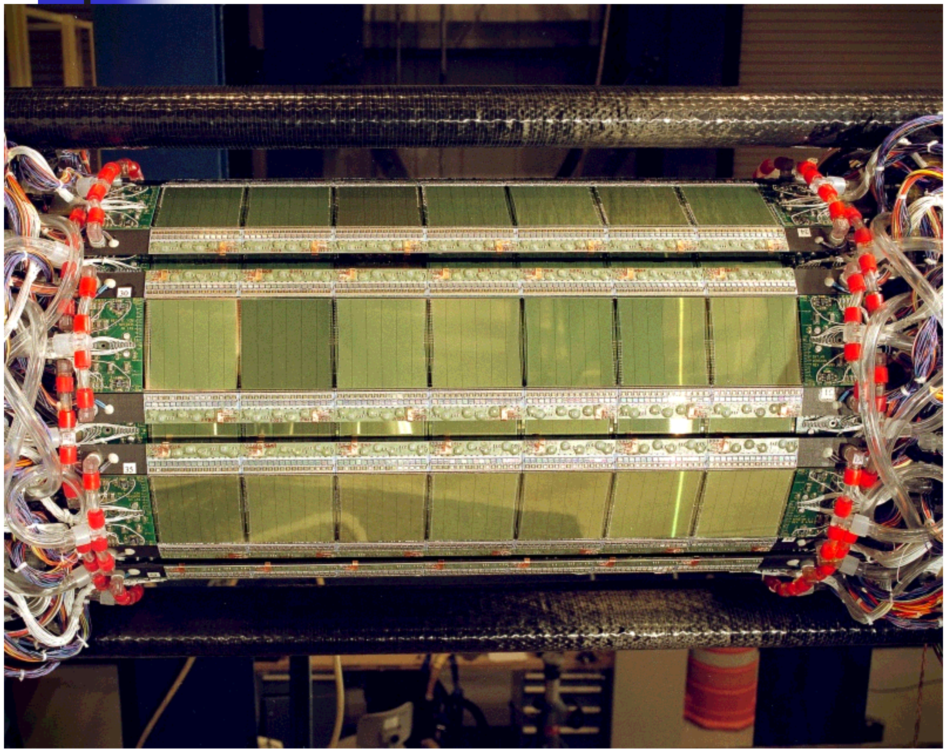
The SVT in STAR

Construction in progress

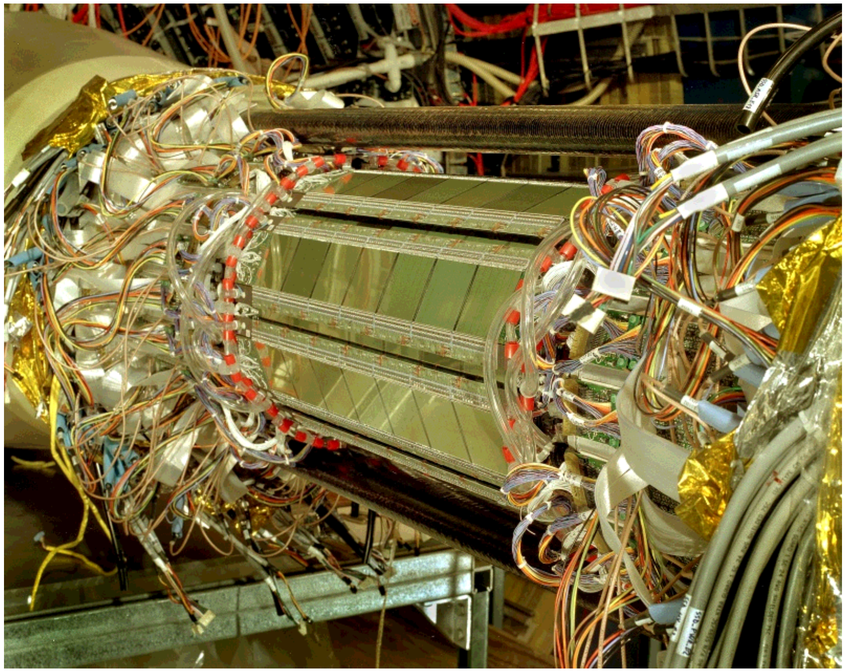


Connecting components

The SVT in STAR



The final device….



… and all its

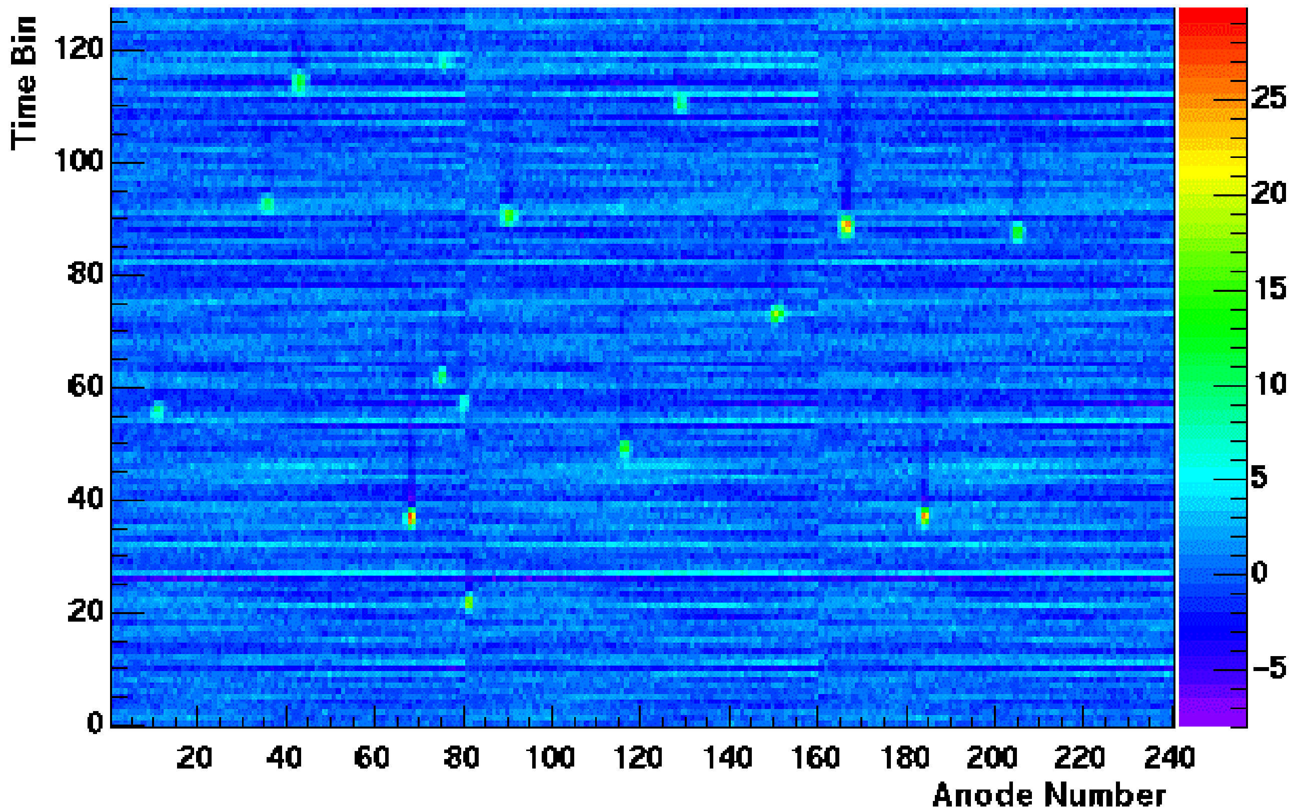
connections

STAR-SVT characteristics

- 216 wafers (bi-directional drift) = 432 hybrids
- 3 barrels, r = 5, 10, 15 cm, 103,680 channels, 13,271,040 pixels
- 6 by 6 cm active area = max. 3 cm drift, 3 mm (inactive) guard area
- max. HV = 1500 V, max. drift time = 5 μs, (TPC drift time = 50 μs)
- anode pitch = 250 μm, cathode pitch = 150 μm
- SVT cost: $7M for 0.7$m^2$ of silicon
- Radiation length: 1.4% per layer
  - 0.3% silicon, 0.5% FEE (Front End Electronics),
  - 0.6% cooling and support. Beryllium support structure.
  - FEE placed beside wafers. Water cooling.

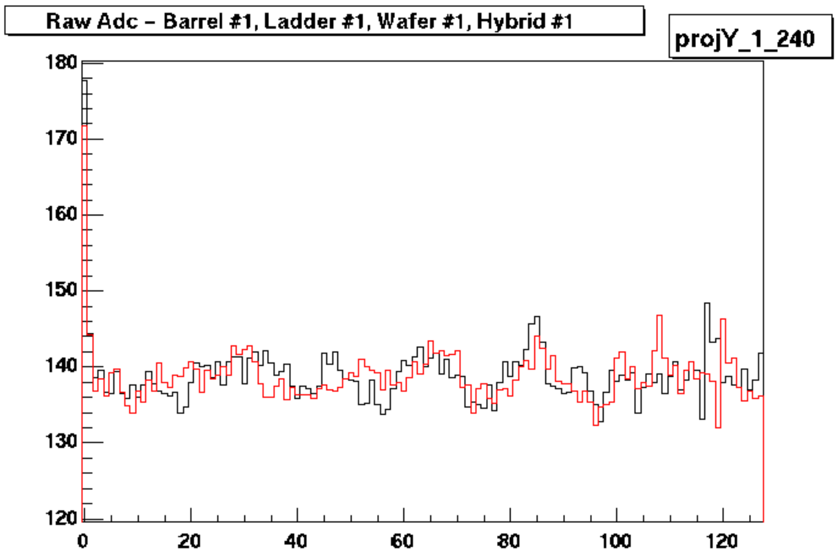
A typical pattern on a hybrid for a central Au-Au event

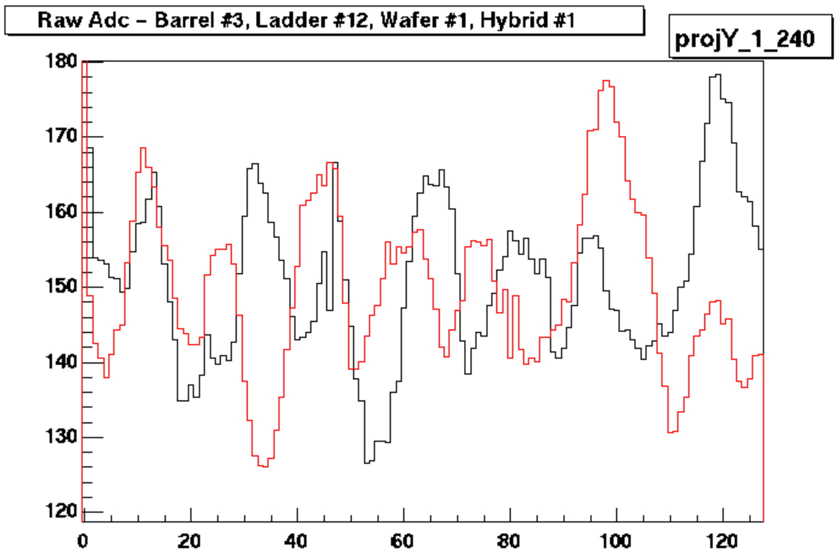
- central event: inner layer: ~15 hits/hybrid (middle: 8 hits, outer: 5 hits)



Problem: 'Common Mode Noise'

- about 20% of the detector shows strong oscillations in raw ADC values

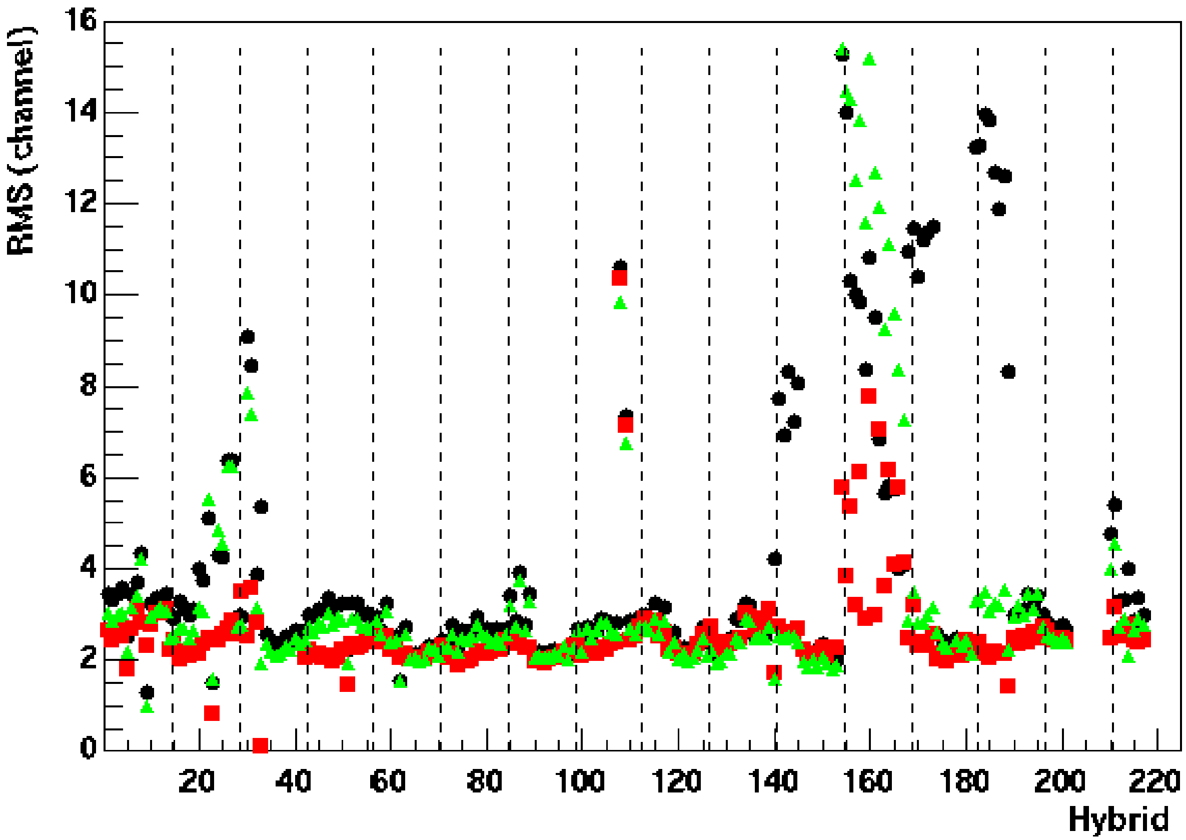




- only a 30% noise increase, data can still be recorded in the noisy hybrids, but zero-suppression can not eliminate noise. Only offline analysis can eliminate noise. Data volume problem.

Noise stable in time and location

- noise pattern in the outer SVT barrel over three days

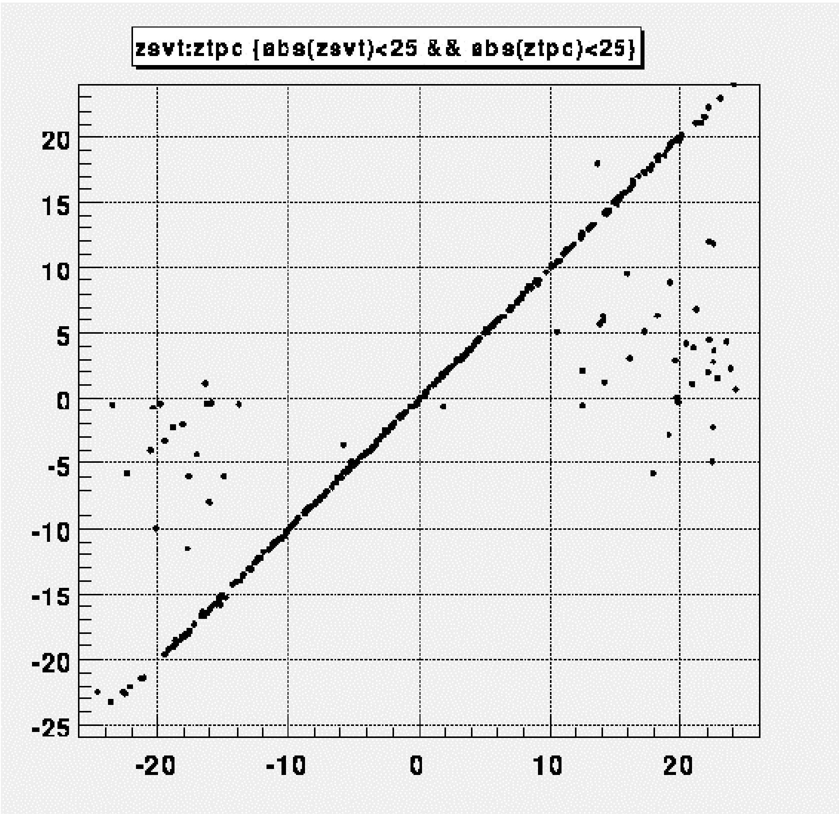


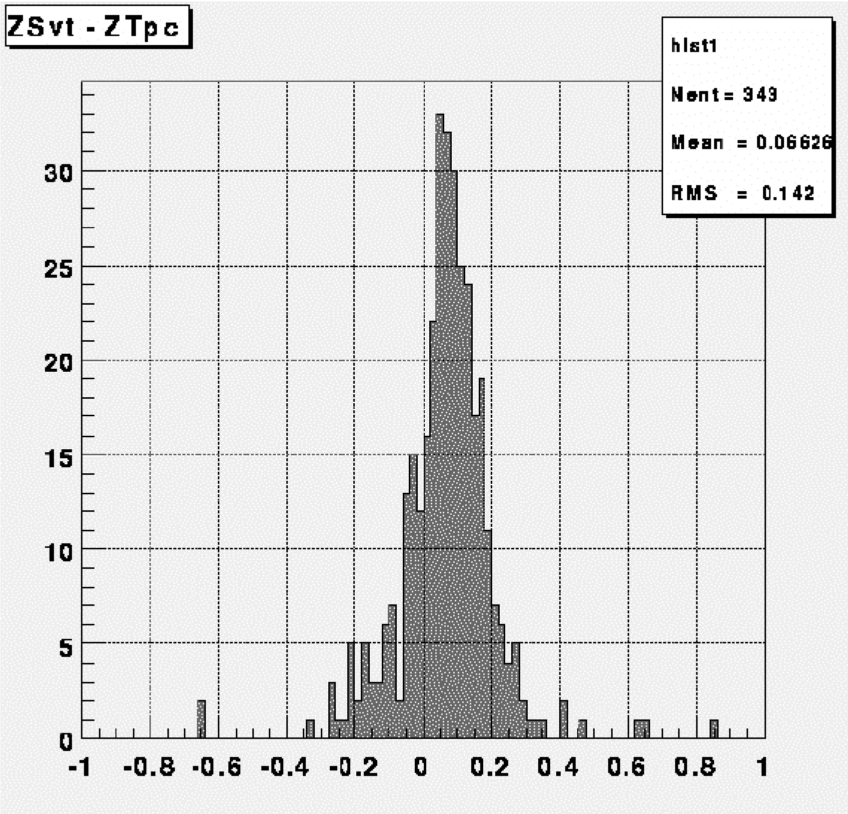
Problem: ‘Common Mode Noise’

- most likely a shielding problem, affects half-ladders
- varies from event to event but not from anode to anode
- data still useable, can be easily subtracted in offline analysis
- can not be subtracted during data taking (zero-suppression)
- data volume in SVT increases six fold from 0.5 to 3 MByte/event
- STAR data volume increases by 30%, slows down data taking
- when the noise level rises, then the threshold requirement for zero-suppression leads to small clusters. Cluster finder has to be optimized for small cluster (down to single anode clusters).

How do we know the data are good ?

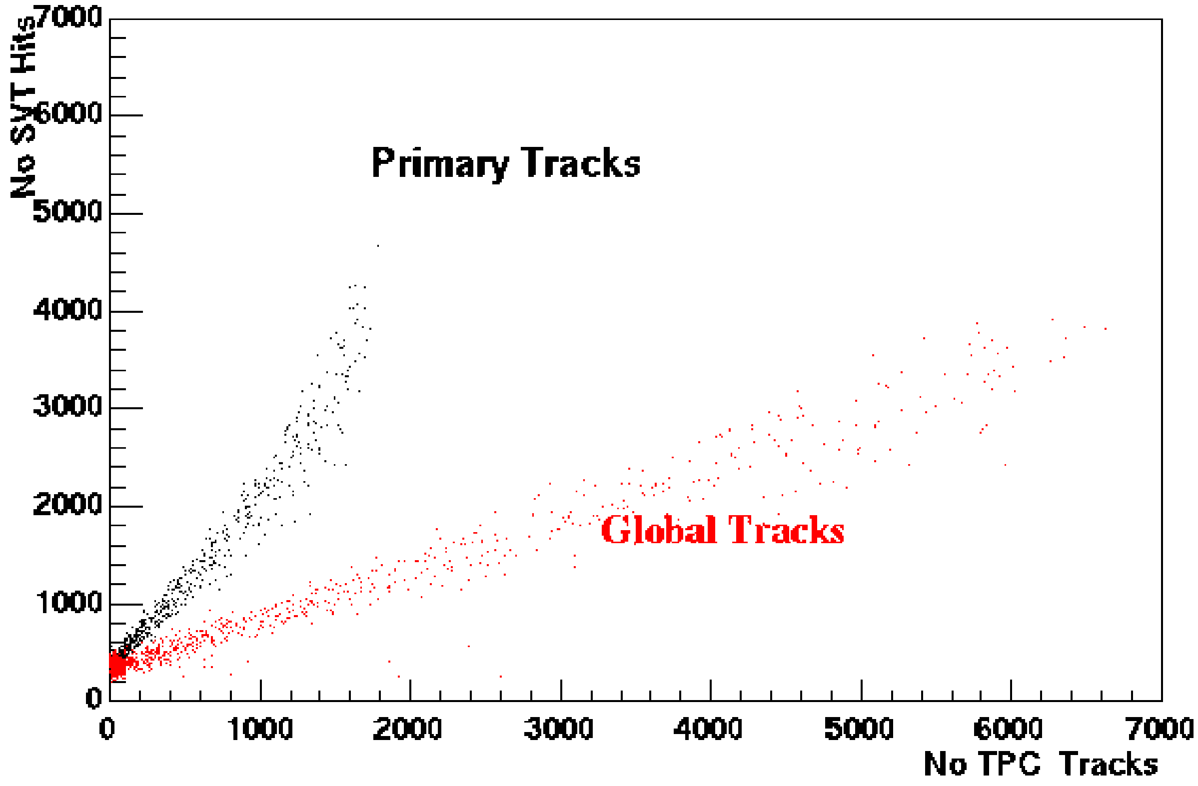
- Test (a): TPC independent primary vertex reconstruction





How do we know the data are good ?

- Test (b): TPC track to SVT hit matching



SVT Operating Experiences (I)

- **after electronics assembly: 99.5% active channels**
- **after mechanical assembly: 97.5% active channels**
- **after full integration: 97% active channels**
- **loss of channels in mechanical assembly. Multiplexing in support lines is necessary but dangerous (e.g. lost 1.5% of channels due to a single HV line disconnect)**

SVT Operating Experiences (II)

- **common mode noise is a problem, good shielding is very important, avoid ground loops**
- **RDO contributes more noise than expected, make sure that RDO (off-detector) is well shielded as well**
- **radiation not a big problem for us. Detector is very robust and can be operated during beam fills and magnet quenches**
- **under-pressure water cooling system is difficult to reliably operate, but detector temperature is very stable**

Forward Physics in STAR

- Charged hadron spectra (pt and rapidity) between η = 2.5-4.0 for AA and pA collisions.
- Separate peripheral collision program
- Important jet physics program in pp and pA.
- V0 reconstruction
- Better phase space for D-meson mass reconstruction through charged hadron channel

New Physics Goals

- Measurements in the baryon-dense regime
  - In central collisions the forward region will be baryon-rich (high baryochemical potential). Exotic phenomena, e.g. centauro-like events and strangelets, are preferably produced in such an environment.
  - this requires measurement of pid, momentum and Z/M ratio with silicon detectors.
  - production of light nuclei and antinuclei carries information of baryochemical potential and of production mechanism in baryon-rich region compared to baryon-poor mid-rapidity region.
  - anti-proton suppression due to increased annihilation ?

New Physics Goals (2)

- Measurements in peripheral collisions
  - study coherent collective effects on nuclei like diffractive and double-pomeron exchange.
  - study exotic meson production for soft double pomeron exchange.
  - study pomeron structure function for hard pomeron exchange with meson states in central rapidity region (requires to measure events with rapidity gap larger than two units).
  - study exotic resonance production in two photon physics for large Z nuclei.

Requirements / Technologies

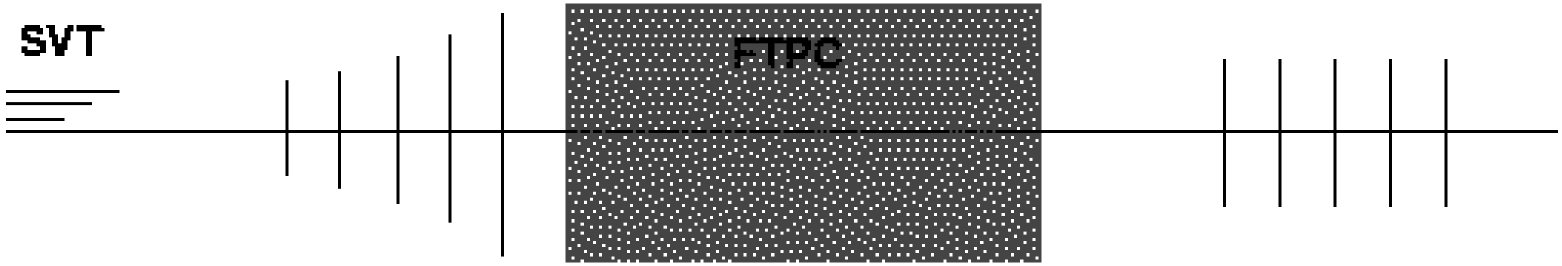
- Requirements:
  - excellent position resolution, good energy resolution
  - good pattern recognition
  - operate at room temperature
  - cost effective, need large coverage (> $1m^2$)
- Technologies:
  - Si Pixel (too expensive ??)
  - CCD (too difficult ??)
  - Si Drift (magnetic field in wrong direction ??)
  - Si Strip (see BABAR, NLC proposal, STAR 4th layer)

Strawman / Potential layouts

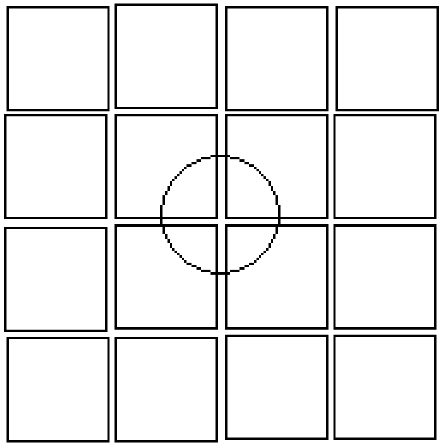
- Strawman technology = Silicon Strip
  - double-sided Silicon Strip detector, 100 micron pitch
  - 5 by 5 cm active area, 1000 channels/wafer
  - 300+320 wafers (see layout below)
  - 0.8 and 0.75 m^2 of active Silicon, respectively
- potential location:in front of FTPC
  - 5 layers (z=60,80,100,120,140 cm ; r=10,15,20,25,30 cm)
  - η = 2.3-4.0 (320,000 channels)
- potential location: behind FTPC
  - 5 layers (z=350,375,400,425,450 cm ; r=20 cm all planes)
  - η = 3.5-5.0 (300,000 channels)

Potential Layouts

- two ‘stations’ in front and behind the FTPC



- develop a quasi-circle
- use square detectors or wedges ?
- use single-sided Si
- have FEE on disk edges
- use TAB Technology ?



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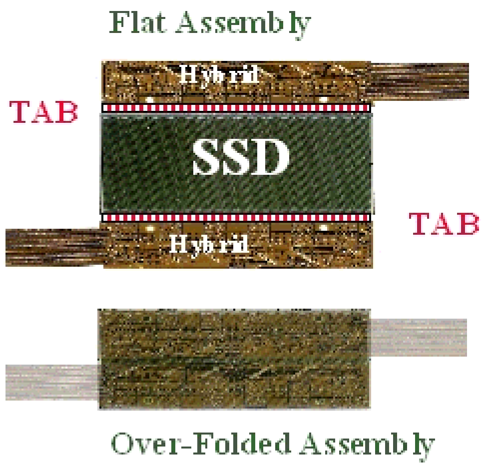
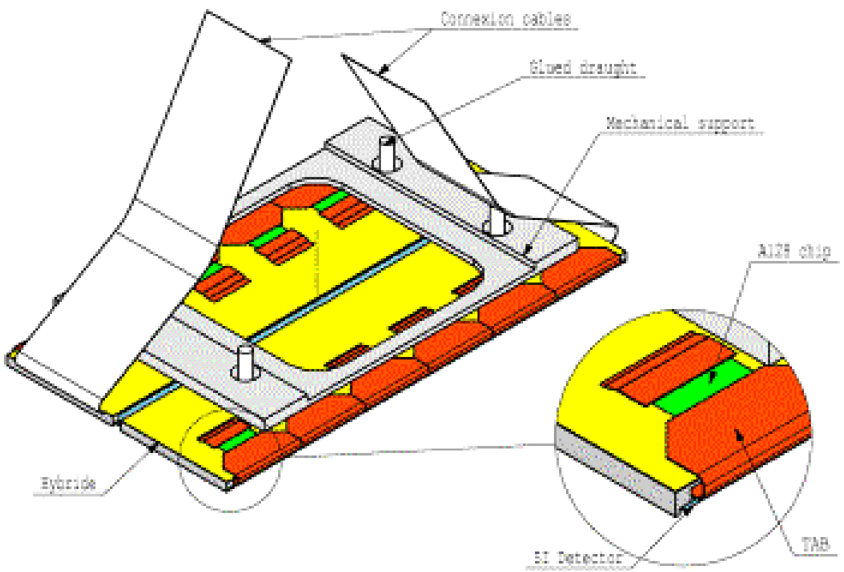
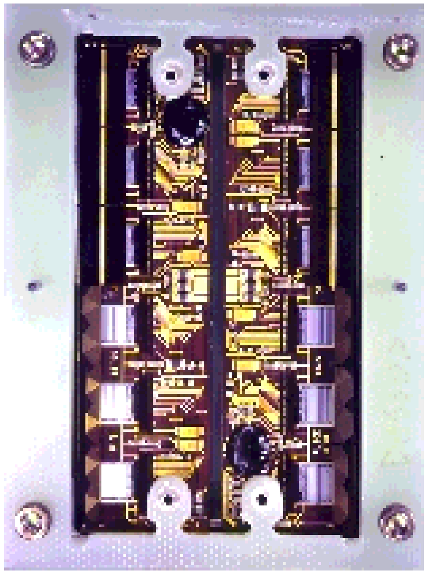
TAB technology

- elegant solution for STAR-SSD developed by THALES







Detection Module

SSD-TAB technology

- SSD solution almost perfect for forward strip detector
- FEE folds to behind the active layer, RDO on the layer edges
- could use double-sided strip detector, ALICE frontend chip, hybrids, bus cables, multiplexer, and ADC boards
- readout pitch too fine (only readout every 2^{nd} strip ? = 190 micron pitch)

Occupancy

- we assume around 1000 charged particles in η=2.5-4

- first layer before FTPC= 16% occupancy
- last layer before FTPC = 1.4% occupancy

- we could vary pitch for different layers
- occupancy not perfectly homogenuous, but close (according to FTPC measurements)

Cost / Manpower / Schedule

- Cost Estimate
  - around $ 4 Million for coverage in front and behind the FTPC (based on 4th layer and NLC cost estimates)
- Manpower
  - need a crew about the size of the SVT project
  - same level of Instrumentation involvement
- Schedule
  - the earlier the better
  - if proven technology is used we should be able to install by 2004

STAR Upgrade (for central tracker)

- Silicon device to replace TPC, Technologies: drift or strip

Five layers of silicon drift detector
Radiation length / layer = 0.5 %
sigma_rphi = 7 μm, sigma_rz = 10 μm
44 m^2 Silicon
Wafer size: 10 by 10 cm
# of Wafers: 4500 (incl. spares)
# of Channels: 3,388,000 channels , (260 μm pitch)

Five layers of silicon strip detector
Radiation length / layer = 0.5 %
sigma_rphi = 10 μm, sigma_rz = ? μm
88 m^2 Silicon
Wafer size: 10 by 10 cm
# of Wafers: 9000 (incl. spares)
# of Channels: 27,104,000 channels , (65 μm pitch)

Layer Radii	Half-lengths
25.00 cm	25.00 cm
50.00 cm	50.00 cm
75.00 cm	75.00 cm
100.00 cm	100.00 cm
125.00 cm	125.00 cm

R. Bellwied, RHIC Workshop

Silicon Drift Detector Features

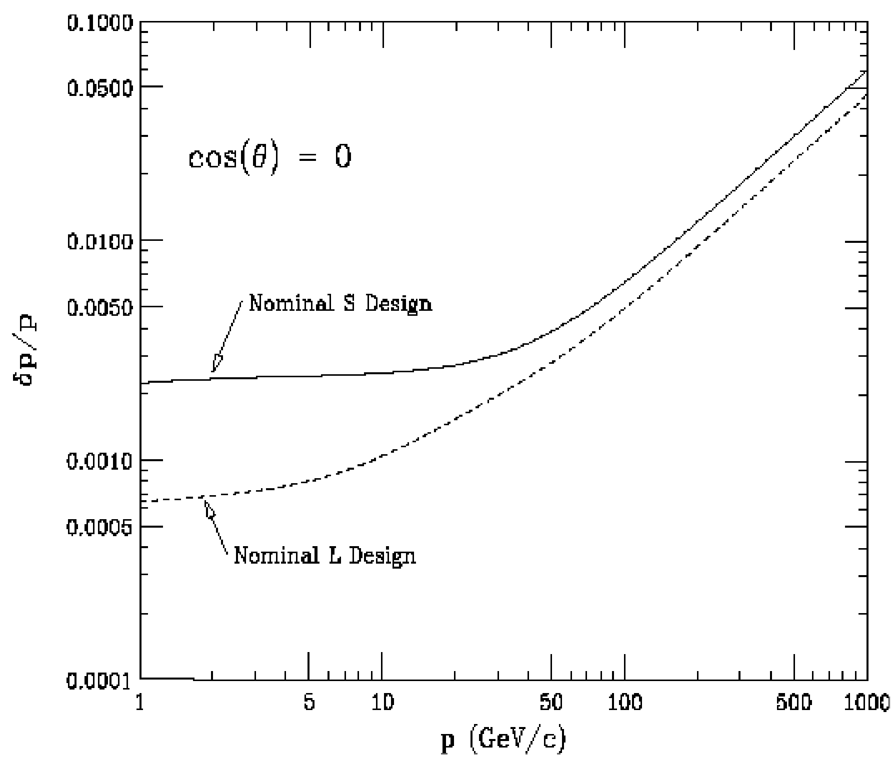
- Mature technology.
- <10 micron resolution achievable with $’s and R&D. Easy along one axis (anodes).
- <0.5% radiation length/layer achievable if FEE moved to edges.
- Low number of channels translates to low cost silicon detectors with good resolution.
- Detector could be operated with air cooling at room temperature

R&D for Large Tracker Application

- **Improve position resolution to 5μm**
  - Decrease anode pitch from 250 to 100μm.
  - Stiffen resistor chain and drift faster.
- **Improve radiation length**
  - Reduce wafer thickness from 300μm to 150μm
  - Move FEE to edges or change from hybrid to SVX
  - Air cooling vs. water cooling
- **Use 6in instead of 4in Silicon wafers to reduce #channels.**
- **More extensive radiation damage studies.**
  - Detectors/FEE can withstand around 100 krad (γ,n)
  - PASA is BIPOLAR (intrinsically rad. hard.)
  - SCA can be produced in rad. hard process.

Simulation Studies

- Momentum resolution
  - Present: 20 µm pos.res., 1.5% rad.length/layer, Beampipe wall thickness: 2 mm
  - Future: 5 µm pos.res., 0.5% rad.length/layer, Beampipe wall thickness: 0.5 mm
- Two Track Resolution.
  - Present: 500 µm
  - Future: 200 µm



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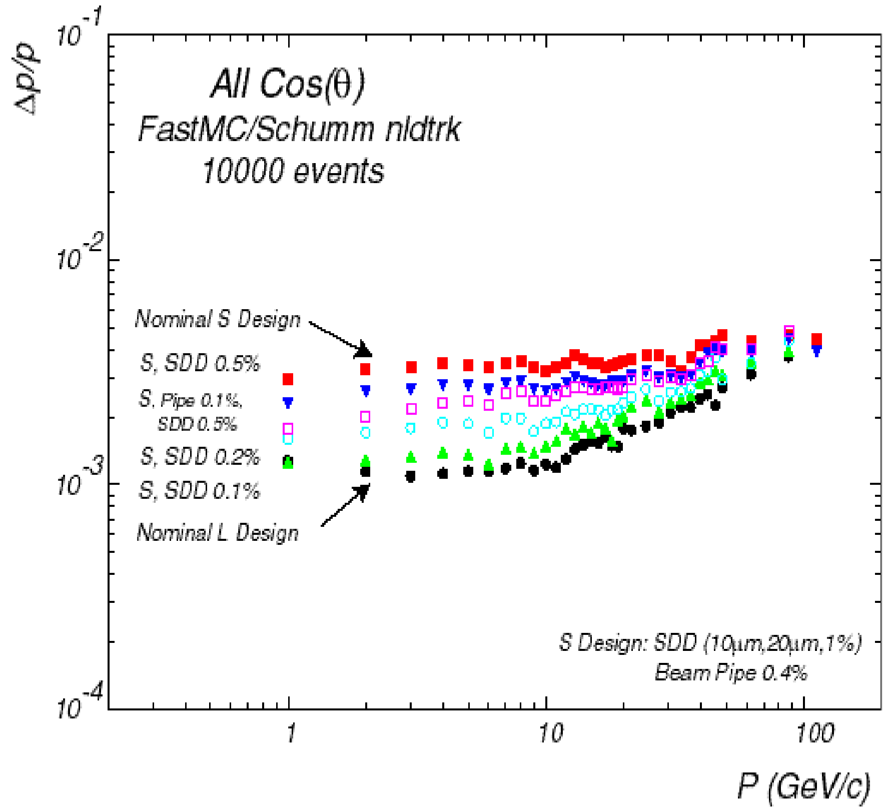
Simulation Studies (cont.)

- Momentum resolution
  - Modify Position Resolution
  - Modify Radiation length: Si thickness, Electronics
  - Modify Beam Pipe Wall Thickness



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Summary

- The STAR experience shows that a Silicon based Vertex Tracker can operate successfully in the RHIC environment.
- The radiation doses and the occupancy are within expectations.
- Certain startup problems have to be expected and anticipated.
- The difficulty in accessing a ‘nested’ detector has to be stressed. The success rate for repair remains to be seen

- STAR is considering a Silicon disk tracker in forward direction, presently based on strip technology
- STAR is potentially considering a large Silicon tracker in case the TPC does not perform well at high luminosities. For that scale only strip and drift detectors seem to be feasible choices. Such a device would take many years to build and would require a construction budget of about $25-30 Million.